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Report No. 2103

January 1971

INTERFACE MESSAGE PROCESSORS FOR THE ARPA COMPUTER NETWORK

QUARTERLY TECHNICAL REPORT NO. 8

1 October 1970 to 31 December 1970

Submitted to:

Advanced Research Projects Agency
Washington, D.C. 20301
Attn: Dr. L.G. Roberts

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1. INTRODUCTION

During the last quarter, we installed IMP No. 13 at Carnegie-Mellon University and IMP No. 14 at Case-Western Reserve University. We also received delivery at BBN of IMP No. 15 for Burroughs Corporation in Paoli, Pennsylvania. During this period, the telephone company has installed three additional circuits, connecting BBN/Harvard, MIT/Lincoln, and Case/Carnegie. The total number of wideband circuits in the net is now equal to 14.

IMPSYS 24, a new version of the IMP program, was released early in November and became operational shortly thereafter. A few minor program bugs were located and corrected during a testing session after its release. Some of the new program features, such as remote crosspatching, have proven extremely helpful in isolating field problems during the last part of the quarter. The new system has proven to be remarkably stable.

We have substantially accelerated our efforts on the design of the terminal IMP. The detailed logic design for the Multi-line Controller is close to completion and a prototype implementation of the controller is scheduled to commence in the next quarter. We are evaluating various devices such as graphics displays, line printers, alphanumeric displays and teletype-like devices for possible utilization with the terminal IMP. We have also begun to investigate the availability of modem equipment on rack-mountable cards to aid in the selection of low- and medium-speed modems for the terminal IMP. This major activity is described in Section 2.

Several new features were incorporated in IMPSYS 24 to provide the Network Control Center with improved summaries of network performance. These features include a short binary status message transmitted every minute to the BBN IMP. In addition, a number of embellishments such as remote light panels have been installed at BBN to upgrade operation of the Network Control Center. Initial statistics have been tabulated on the reliability of the IMPs and wideband circuits. This activity is described in Section 3.

A study was conducted to understand the relationships between buffer allocation, the routing algorithm, Host protocol, and subnet performance. This study is expected to terminate early in the next quarter. Our objectives in trying to understand these relationships are described in Section 4.

In addition, we pursued a number of diverse activities such as arranging for the output signals on the standard IMP/Modem interface to be compatible with the RS232C standard, reviewing the available facsimile equipment for possible application to the ARPA Network, preparing to collect and have distributed a set of information describing Host resources, and working cooperatively with AT&T toward the resolution of the issues of a central plant control for the communication circuits. Finally, we issued a revised version of BBN Report No. 1822, *Specifications for the Interconnection of a Host and an IMP*, and Report No. 1877, *Operating Manual*.

2. TERMINAL IMP

During this quarter, the detailed logic design of the Multi-line Controller portion of the terminal IMP proceeded almost to completion. The controller is organized into common logic shared by all the terminals, plus line specific logic in the form of one line-interface card per terminal device. The common logic transfers characters to and from the computer via the high-speed DMC channels and buffers characters for both input and output. The line-interface card contains the necessary drivers, receivers, single-bit buffers and synchronizers to handle either synchronous or asynchronous lines. In addition, the card has provision for monitoring and setting modem control signals.

The line-interface card has connectors at both ends, one for connecting to the Multi-line Controller common logic bus and the other suitable for direct cable connection to an RS232C interface. The provision allows flexible interconnection of ports on the Multi-line Controller to modems and terminal devices without a separate patch panel.

We have completed the initial mechanical design and physical layout of the Multi-line Controller and the Terminal IMP. The controller, the DDP-316, the interfaces, and the modem equipment will be housed in a standard Honeywell highboy rack. The size of the Terminal IMP will be approximately the same size as the 516 IMP. A schematic diagram of the planned terminal IMP configuration is shown in Figure 1.

The space at the bottom of the enclosure will be dedicated to housing line-interface cards, modems, and other communication equipment. We are currently evaluating modem equipment suitable for rack mounting. We estimate that *at least* 20 modems of the 103 or 202 variety (or 10 of the 201 variety) can be accommodated

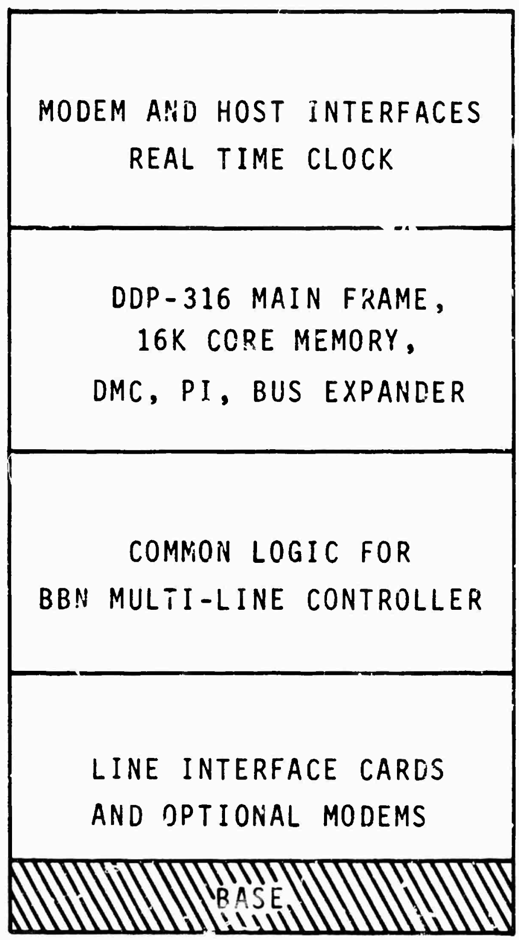

Figure 1 Terminal IMP Configuration — Front View

in the same enclosure with the Terminal IMP. Another cabinet may be required to house additional modems.

A wide range of terminal equipment is being reviewed to select a representative set of high-quality terminals for use with the prototype terminal IMP. We have had demonstrations of slow and fast line printers, teletype-like terminals alpha-numeric and graphics CRT display terminals. We are also considering the issues associated with connecting card readers, magnetic tape recorders, facsimile devices and other peripheral equipment to the terminal IMP. Selection of a set of terminals will be made early next quarter.

Delivery of a prototype 316 IMP is expected to occur during the next quarter. The 316 will be a lower cost version of the 516 IMP (by a factor of about 2). Both the 316 and 516 will contain essentially *identical programs*. The 316 IMP can be upgraded to a terminal IMP by incorporating a Multi-line Controller.

In the last Quarterly Techrical Report, we indicated that the Multi-line Controller would handle terminal devices "on input and output at speeds up to and including 19.2 kilobits/sec." More precisely, this text should read "on input and output at synchronous speeds up to and including 19.2 kilobits/sec. The maximum allowed input rate from asynchronous devices is 2400 bits/sec. The maximum output rate to asynchronous devices is 19.2 kilobits/sec." A list of the allowed speeds is given in Table 1 below.

TABLE 1

SYNCHRONOUS		ASYNCHRONOUS
All synchronous speeds up to and including 19.2 kilobits/sec.		75 bits/sec. 110 134.5 150 300 600 1200 1800 2400 4800 ⎤ on output only 9600 ⎥ 19,200 ⎦

3. NETWORK CONTROL CENTER

Summary statistics on the number and duration of circuit outages, for the period June 1 to December 31, 1970, are shown in Figure 2. Percent down time on the circuits ranged from 0-7% (excluding the Harvard/BBN circuit, which has had an intermittent problem). Down time prior to phone company notification is included in the outage figures. Thus, the figures represent the total time that a circuit is unavailable for network use due to circuit failure.

Summary statistics on IMP down time, for the period from September 1 to December 31, 1970, are shown in Figure 3. The summary figures show both total down time and unscheduled IMP down time. Normal down time on the IMPs *for all reasons* has ranged from 0-6% (excluding Stanford's IMP, which has had an intermittent problem). However, a substantial amount of *scheduled* down time has occurred in this period for testing and retrofitting.

A new reporting mechanism was incorporated into the IMP program to allow more accurate and expanded summaries of network status. This new report is a ten-word binary status message that is sent once a minute from each IMP to the Network Control Center. Failure to receive a status message from an IMP for a period of about 3 minutes results in an indication on the summary status sheet that the IMP is dead.

This status message contains.

1) The IMP number;

2) The up/down status of the real Hosts and the phone lines;

3) For each phone line, a count of the number of HELLO messages which failed to arrive during the last minute;

4) For each phone line, a count of the number of packets transmitted in the last minute for which acknowledgments were received; and

5) A count of the number of packets transmitted by each real Host into its IMP.

A status report program that runs in the prototype IMP at BBN currently receives these binary status messages and composes an hourly summary of network status that is printed on a teletype in the Network Control Center. In Figure 4, we show the numbering scheme currently in use to identify lines and IMPs in the network. An annotated hourly summary sheet is shown in Figure 5.

CIRCUIT	OUTAGE (HR:MIN)	#OUTAGES	%
BBN/Harv*	199.17	9	19.8
BBN/Rand	472:53	20	9.21
Utah/SDC	300:22	18	5.85
MIT/Utah**	279:00	54	5.84
BBN/MIT	139:27	10	2.72
SRI/Utah	115:08	7	2.24
UCLA/Rand	103:46	2	2.02
UCLA/SRI	66:17	9	1.29
SRI/UCSB	34:24	2	0.67
SRI/Stanford***	22:00	1	0.54
Rand/Stanrord***	8:24	1	0.21
Rand/SDC	2:07	1	0.041
UCSB/UCLA	0:00	0	0.0
Lincoln/MIT****	0:00	0	0.0

*Installed 19 November 1970

**Installed 15 June 1970

***Installed 15 July 1970

****Installed 30 December 1970

Figure 2 Summary of Circuit Outages (1 June to 31 December 1970).

Only recorded circuit outages of over 30 minutes duration have been included in these statistics.

IMP SITE	DOWN TIME*	#TIMES DOWN*	PERCENT DOWN*
Stanford	413:00 (406:04)	20 (18)	14.11 (13.87)
Rand	174:54 (79:43)	19 (3)	5.97 (2.72)
UCLA	158:38 (123:36)	16 (5)	5.42 (4.22)
BBN	143:03 (125:15)	14 (7)	4.89 (4.28)
UCSB	129:15 (128:45)	5 (4)	4.41 (4.40)
SRI	110:47 (5:27)	13 (2)	3.78 (0.19)
Utah	96:48 (44:14)	9 (5)	3.31 (1.51)
MIT	64:35 (16:28)	13 (4)	2.21 (0.56)
Harvard**	11:11 (2:24)	4 (1)	1.11 (0.24)
SDC	2:29 (0.00)	3 (0)	0.08 (0.00)

*Number in parentheses refer to unscheduled time.

**Harvard joined the network on 19 November 1970.

Figure 3 IMP Down Time Summary (1 September to 31 December 1970).†

†Only recorded IMP outages of over 30 minutes duration have been included in these statistics. Scheduled outages refer to down time for maintenance, testing, retrofits, etc.

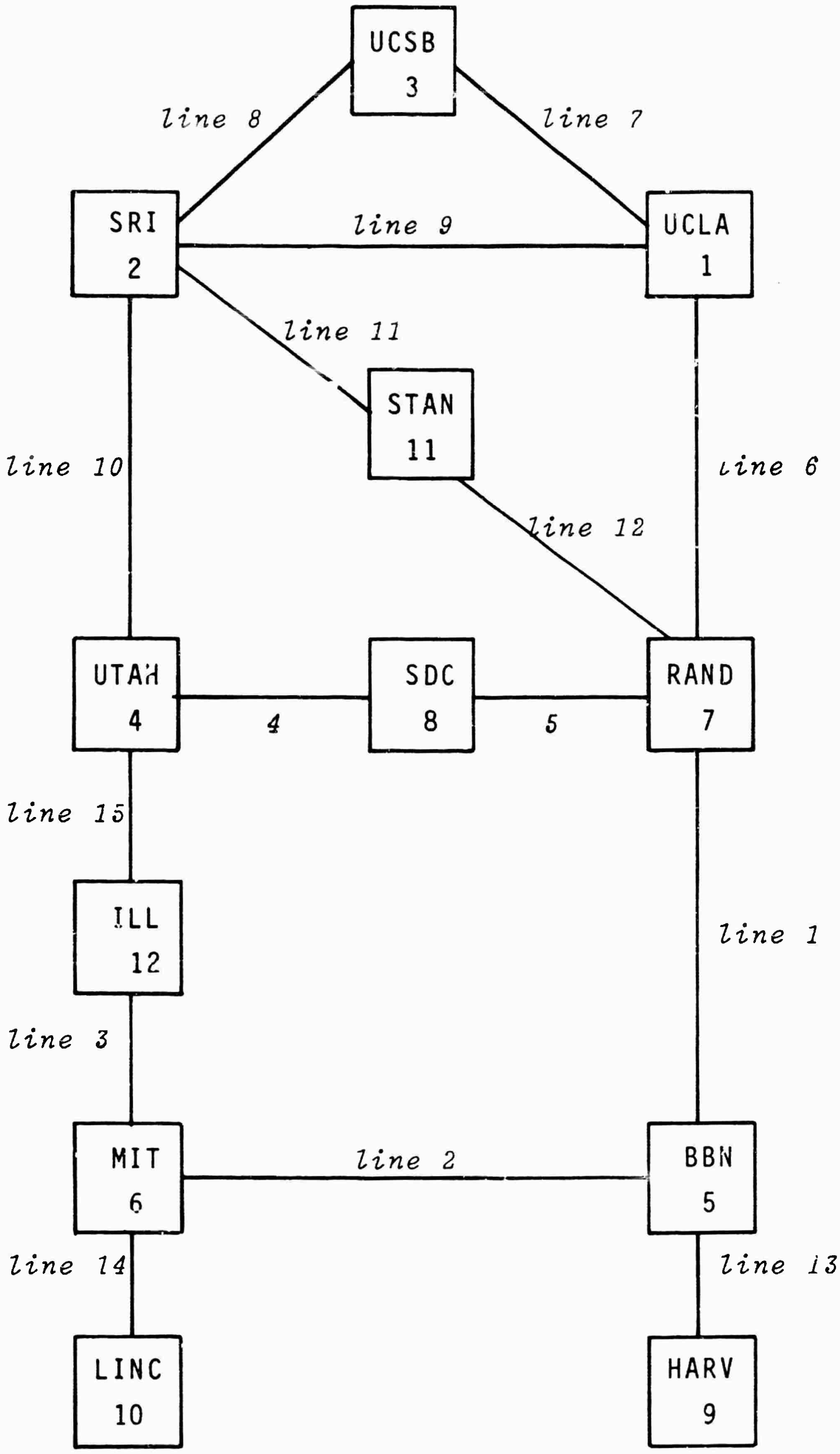

Figure 4 IMP and Circuit Numbers

DAY 28 MONTH 12 YEAR 70

Date

*********IMP STATUS*********

TIME	01	02	03	04	05	06	07	08	09	10	11	12	13	14
	IMP SITES													
2100	1	1	1	1	1	1	1	1	1	*	1	*	*	*

Status of IMP sites
1 → UP
* → DOWN
(Refer to Figure 3.)

*********LINE STATUS*********

TIME	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
	NETWORK LINES														
2100	1	1	1	1	1	1	1	1	1	1	1	1	1	*	*
2103	1	1	*	1	1	1	1	1	1	1	1	1	1	*	*
2104	1	1	1	1	1	1	1	1	1	1	1	1	1	*	*
2109	1	1	*	1	1	1	1	1	1	1	1	1	1	*	*
2110	1	1	1	1	1	1	1	1	1	1	1	1	1	*	*
2120	1	1	*	1	1	1	1	1	1	1	1	1	1	*	*
2143	1	1	1	1	1	1	1	1	1	1	1	1	1	*	*
2146	1	1	*	1	1	1	1	1	1	1	1	1	1	*	*
2150	1	1	*	*	1	1	1	1	1	1	1	1	1	*	*
2152	1	1	*	1	1	1	1	1	1	1	1	1	1	*	*

Status of Circuits
1 → UP
* → DOWN
? → INFORMATION UNAVAILABLE
(Refer to Figure 3.)

*********LINE ERRORS THROUGHPUT*********

LINE	ERRORS(+/-)	THROUGHPUT(+/-)
01	00000/00066	0000000490/0000000557
02	00000/00000	0000000139/0000000490
03	01479/03521	0000000027/0000001104
04	00000/00070	0000000052/0000000049
05	00000/00000	0000000132/0000000145
06	00000/00000	0000000198/0000000181
07	00122/00000	0000000074/0000000074
08	00063/00000	0000000000/0000000000
09	00000/00000	0000000000/0000000000
10	00000/00000	0000001006/0000001172
11	00000/00000	0000000106/0000000111
12	00000/00000	0000000175/0000000180
13	00000/00000	0000000060/0000000074
14	00000/00000	0000000000/0000000000
15	00000/00000	0000000000/0000000000

Line errors (+/-) indicate the number of Hello's that failed to be received on that line.

Throughput (+/-) indicates the number of packets for which acknowledgments were received on that line.

+ → count at higher # IMP
− → count at lower # IMP

*********HOST THROUGHPUT*********

IMP SITE	HOST ONE	HOST TWO	HOST THREE
01	0000000000	0000000000	0000000000
02	0000000886	0000000000	0000000000
03	0000000000	0000000000	0000000000
04	0000000120	0000000000	0000000000
05	0000000000	0000000000	0000000000
06	0000000000	0000000000	0000000000
07	0000000000	0000000000	0000000000
08	0000000000	0000000000	0000000000
09	0000000000	0000000000	0000000000
10	0000000000	0000000000	0000000000
11	0000000000	0000000000	0000000000

Host throughput indicates, for each of three Hosts, the number of packets transmitted from the Host into its IMP.

Figure 5 Sample of Hourly Summary Information from 21:00 to 22:00 on 23 December 1970.

4. THROUGHPUT AND PROTOCOL STUDY

The basic subnet communication protocol and routing algorithm were developed over two years ago. These procedures have remained essentially unchanged as the net has evolved, and subnet performance under *moderate load* has proven to be excellent. However, it has become increasingly clear that certain undesirable characteristics can occur under heavy traffic load. Specifically, when many links are in use to a given destination IMP and high throughput is attempted on these links, the present RFNM scheme does not, in all cases, prevent congestion at a destination IMP.

In addition to this technical problem, two other items are noteworthy:

1) The development in 1970 of an initial Host protocol emphasized the question of the proper relation between IMP/IMP protocol and Host/Host protocol;

2) As the IMP program has continued to increase in size, the number of packet buffers available in the 12K core memory has steadily decreased.

These circumstances have underscored for us the importance of understanding in detail the relation between the number of IMP buffers, the routing algorithm, Host protocol and subnet performance. An intensive study was initiated during this quarter to review these issues and to seek improved algorithms that provide efficient performance under heavy traffic load. The study has been proceeding in a useful fashion. It is already clear that the study will result in several IMP/IMP protocol changes.

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13. ABSTRACT

The basic function of the IMP computer network is to allow large existing time-shared (Host) computers with different system configurations to communicate with each other. Each IMP (Interface Message Processor) computer accepts messages for its Host from other Host computers and transmits messages from its Host to other Hosts. ~~Since~~ there will not always be a direct link between two Hosts that wish to communicate, individual IMPs will, from time to time, perform the function of transferring a message between Hosts that are not directly connected. This then leads to the two basic IMP configuration -- interfacing between Host computers and acting as a message switcher in the IMP network. The message switching is performed as a store and forward operation. Each IMP adapts its message routine to the condition of those portions of the IMP network to which it is connected. IMPs regularly measure network performance and report in special messages to the network measurement center. Provision of a tracing capability permits the net operation to be studied comprehensively. An automatic trouble reporting capability detects a variety of network difficulties and reports them to an interested Host. An IMP can throw away packets that it has received but not yet acknowledged, transmitting packets to other IMPs at its own discretion. Self-contained network operation is designed to protect and deliver messages from the source Host to the destination IMP.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Computers and Communication						
Store and forward communication						
ARPA Computer Network						
Honeywell DDP-516						
IMP						
Interface Message Processor						